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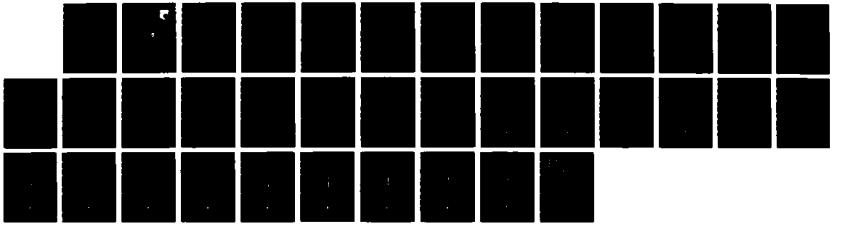

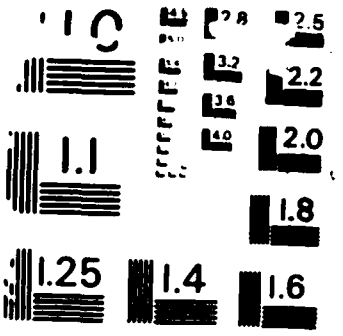

TEST CHART

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ACOUSTICAL ANALYSIS OF A TEST HORN

Young In Moon
Rocky R. Arnold

ANAMET LABORATORIES, INC.
3400 Investment Boulevard
Hayward, CA 94545-3811

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The natural frequencies and mode shapes for three models of a small test horn are determined using the 3-D acoustic finite element computer program COMIC (COMplex AcoustIC Pressure Analysis). The mode shapes are presented graphically and nodal planes are identified. Placing a wall of blocks and a missile inside the model does not make any significant change in natural frequencies, although the nodal planes have moved in the direction of the added elements.

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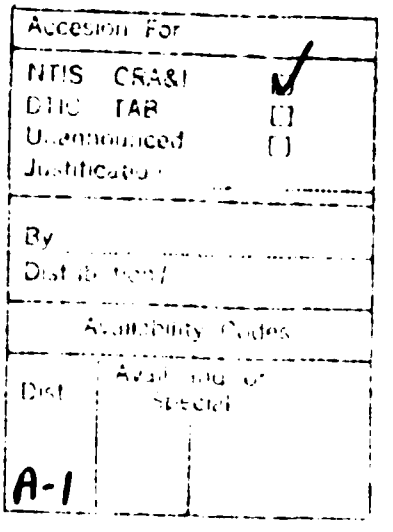
PREFACE

This acoustical analysis of a small test horn was performed by the Aerospace Structures Information and Analysis Center (ASIAC), which is operated by Anamet Laboratories, Inc. under Contract No. F33615-84-C-3216 for the Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories.

This report was prepared by Dr. Young In Moon, and approved by Dr. Rocky R. Arnold. The investigation was performed as part of ASIAC Problem No. 506-1.



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1.0 INTRODUCTION

This study was performed to determine natural frequencies and mode shapes of a small test horn using a computer program COMIC (COMplex AcoustIC Pressure Analysis), which was developed by Battelle Columbus Laboratories of Columbus, Ohio.

COMIC is an acoustic finite element code which performs a three-dimensional steady-state pressure analysis due to harmonic boundary conditions associated with an acoustic medium, and determines acoustic pressure, natural frequencies, and the associated mode shapes where the pressure and its derivatives are normalized to unity.

Reference 1 contains features and capabilities of COMIC, and a brief statement of theoretical development and several example problems with listings and computer printouts.

The full capabilities and accuracy of the program were evaluated in Reference 2 by comparing the finite element results to the analytical, experimental, and other numerical techniques. Reference 2 shows that COMIC provides excellent results for problems determining frequencies and mode shapes.

2.0 MODEL FOR ANALYSIS

Figure 1 is the side view of a small-scale facility test horn which has a rectangular cross section up to L=180 inches measured from the back wall and has a square cross section from L=180 inches to L=448 inches. Starting at L=448 inches, the test horn transitions from a square cross section to a circle for one air modulator configuration. For two air modulators, the test horn divides into two identical tapered parts, each 45 inches long. The distance between the geometric centers of each separated tapered part is 18 inches.

2.1 First Model -- L-384 Inches

Shown in Figure 2 is the finite element model for analysis. Two types of models were run for comparison. The coarse model has 375 grid points and 224 solid elements, while the finer one has 620 grid points and 400 solid elements. The results are shown in the first two columns of Table 1. A comparison of the results indicates that the difference in frequencies are negligible. Therefore, the coarse model was used in running the three following cases:

(1) Straight Blocks and Missile: A straight block wall 17 inches thick is placed at 20 inches parallel from the back wall, reaching half the height of the ceiling. In addition, a 95-inch-long missile is also placed axially at X=168 inches.

(2) Irregular Blocks and Missile: Blocks are laid such that the back of the block wall is parallel to the back wall, while the front side is jagged.

(3) Tilted Blocks: Blocks are piled to make an angle with the back wall. This case does not have a missile.

2.2 Second Model -- L=448 Inches

This model is constructed by adding a cavity 64 inches long with a constant cross section 12 inches by 12 inches to the right-end of the first model. Two cases are considered - no cavity and tilted blocks only.

2.3 Full Model -- L=503 Inches

Figure 3 is the finite element model for analysis where a Y-shaped and tapered section is included. The source of sound is at the end of the model (X-503 inches).

3.0 RESULTS

3.1 Natural Frequencies

Table 1 contains the acoustic natural frequencies of all models considered in this report. The results from the coarse model show excellent agreement with those from the finer model. We found that placing blocks and a missile inside the model did not make a significant change in frequencies. This is because the longitudinal mode becomes dominant at lower frequencies and the wave length becomes much larger than the thickness of the block wall. Another reason may include the fact that the blocks are piled up only half the height to the ceiling, and thus do not contribute much in changing the size or shape of the model. However, the increase of the length of the model reduces natural frequencies as expected.

3.2 Mode Shape

For the natural frequency analysis, the output of a COMIC run contains acoustic pressure at grid points and its partial derivatives, and they are normalized to unity.

As there was a need for graphical display of the structural model and computer-generated output, a program was written to convert the COMIC output data into the one which operates on CADS (Computer Aided Design System) using DI-3000 graphics package. Reference 3 presents detailed user instructions for CADS.

The numerical values of acoustic pressure differences are represented by eigenvectors in CADS, and CADS displays the eigenvectors mode shape data at the node.

From Figures 4 through 19, the top view of the original geometry was drawn using a solid line, and mode shapes are represented by a dotted line which connects tips of eigenvectors at grid points. A positive pressure difference may be identified by an arrow going in the right and upward direction when two corresponding grids are connected.

A node point is the crossing point of a solid line with a corresponding dotted line, and a node line is constructed by simply connecting these node points. This is shown in Figures 5 and 6. Mode shapes of the three models are plotted in Figures 4 through 19 using a top plate with an open window as an example.

Figure 4 shows an original finite element model of the top plate in solid lines and a mode shape of the first model (L=384 inches) at the first frequency (13.802 Hz) in dotted lines. The window is represented by the area crossed, and the pressure difference around the window becomes zero as shown in the figure.

Determination of the correct sign of an eigenvector is illustrated by taking as an example a point at the lower left corner in the figure. This point on the solid line is shifted to the upper right position on the dotted line, and thus a vector connecting these two points is positive, and a positive acoustic pressure is present at that point. As this is true over the surface of the plate and no line crosses its original solid line, the pressure becomes positive all over in the cavity, thus producing mode (0,0,0), which is believed to be analogous to a rigid body motion in a structure analysis.

Figure 5 shows a mode shape at the second frequency (30.637 Hz) and is different from the first mode. Following the bottom line shows that the acoustic pressure difference starts with a negative value, but becomes positive after the dotted line crossed over the solid line, producing a node point at X=151 inches. Other node points are all at the same X-coordinate but at different Y-coordinates. Therefore, a node line parallel to the Y-axis is drawn as shown in Figure 5. As this is true in all other X-Y planes along Z-axis, a node plane can be identified as a Y-Z plane at X=151.04 inches and the node becomes (1,0,0).

The third mode in Figure 6 has two node planes, X=106.44 inches, and X=275.8 inches. A mixed node (2,1,0) is shown in Figure 8.

Mode shapes in Figures 9 through 13 are drawn for the second model (L=448 inches) using the same top plate with an open window but extended longitudinally, and those in Figures 14 through 19 are for the full model (L=503 inches).

A comparison of Figures 5, 10, and 15 reveals that the first node plane moves toward the direction of adding elements. In fact, the first node plane is present at X=151.04 inches for the first model (L=384 inches) in Figure 5, and at X=244.50 inches for the second model (L=448 inches) in Figure 10, and at X=244.50 inches for the full model (L=503 inches) in Figure 15.

4.0 CONCLUSIONS

A small-scale facility test horn was analyzed by making use of the three-dimensional acoustic finite element computer code COMIC. Acoustic natural frequencies and mode shapes are obtained for three different models.

Mode shapes are presented graphically using CADS, and node planes are identified.

We found that placing a wall of blocks and a missile inside the model does not make any significant change in natural frequencies, and that the node planes have moved in the direction of added elements.

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1. Faulkner, L. L., Koenig, M., and Workman, G., "User's Manual for COMIC -An Acoustic Finite Element Computer Code," ASIAC Report No. 484.1A, April 1984.

2. Rencis, J. J., "Three-Dimensional Finite Element Acoustic Analysis," AFWAL-TM-84-223.

3. Less, M. C. and Manual, S., "CADS - A Computer Aided Design System, Vol. II - User's Guide," AFWAL-TR-85-3066, Aug 1985.

TABLE 1

SMALL TEST HORN --- NATURAL FREQUENCIES (Hz)

Mode	L=384 Inches					L=448 Inches		L=503 Inches
	No Cavity		Straight Blocks & Missile	Irregular Blocks & Missile	Tilted Blocks Only	No Cavity	Tilted Blocks Only	No Cavity (Full Model)
	Finer	Coarse						
1	13.486	13.802	13.789	13.771	14.340	13.632	13.500	13.512
2	30.617	30.637	31.336	31.318	31.167	22.213	22.195	19.392
3	37.907	38.078	38.573	38.532	38.951	34.384	34.366	33.923
4	55.213	55.830	56.760	56.665	56.397	48.068	48.180	45.667
5	70.215	71.165	71.709	71.368	71.815	62.551	62.918	59.203
6	71.633	71.145	71.805	72.699	71.480	71.576	71.744	71.374
7	79.774	77.508	81.545	81.200	81.748	75.594	76.077	70.381
8	87.720	85.251	86.976	87.957	85.654	80.172	80.874	79.736
9	84.944	87.107	90.257		91.444	85.218	86.007	84.502
10	88.549		92.402			87.899		

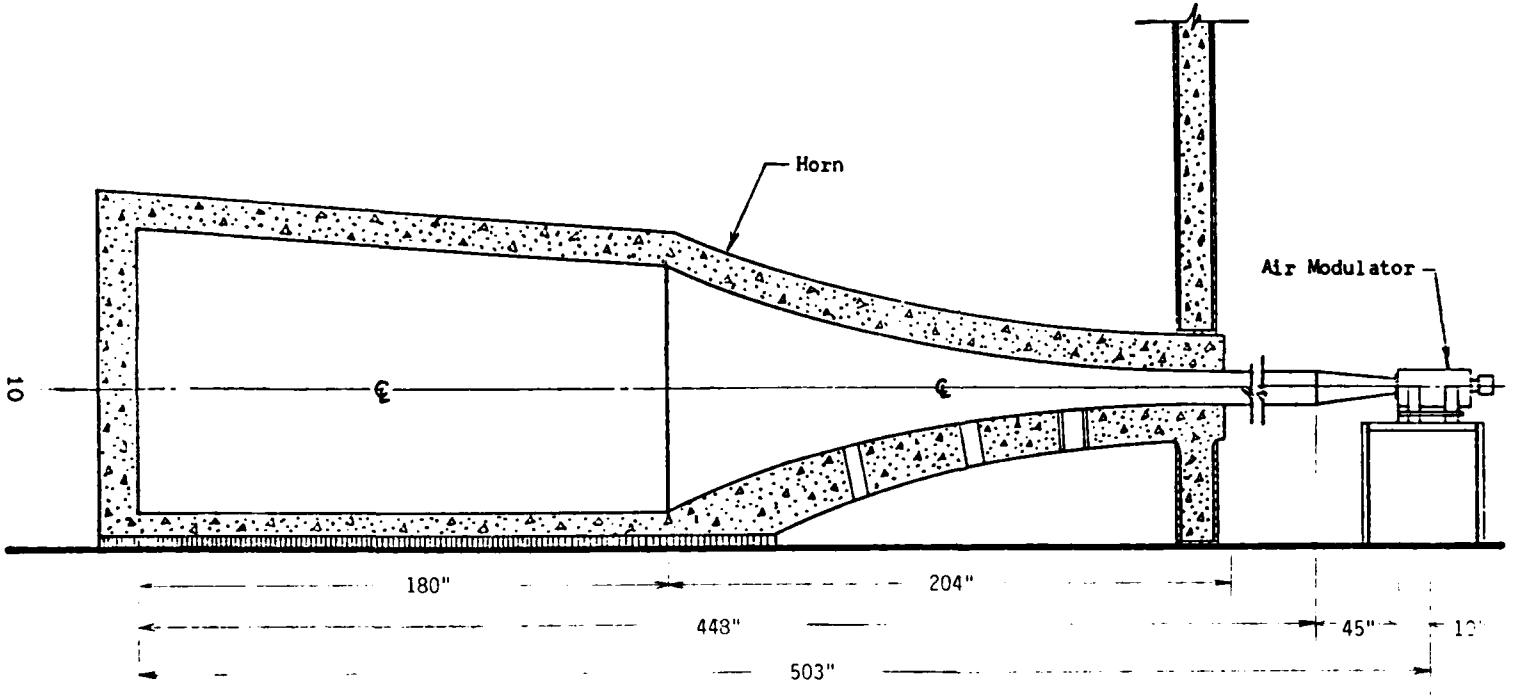

Figure 1 Small-Scale Facility Test Horn

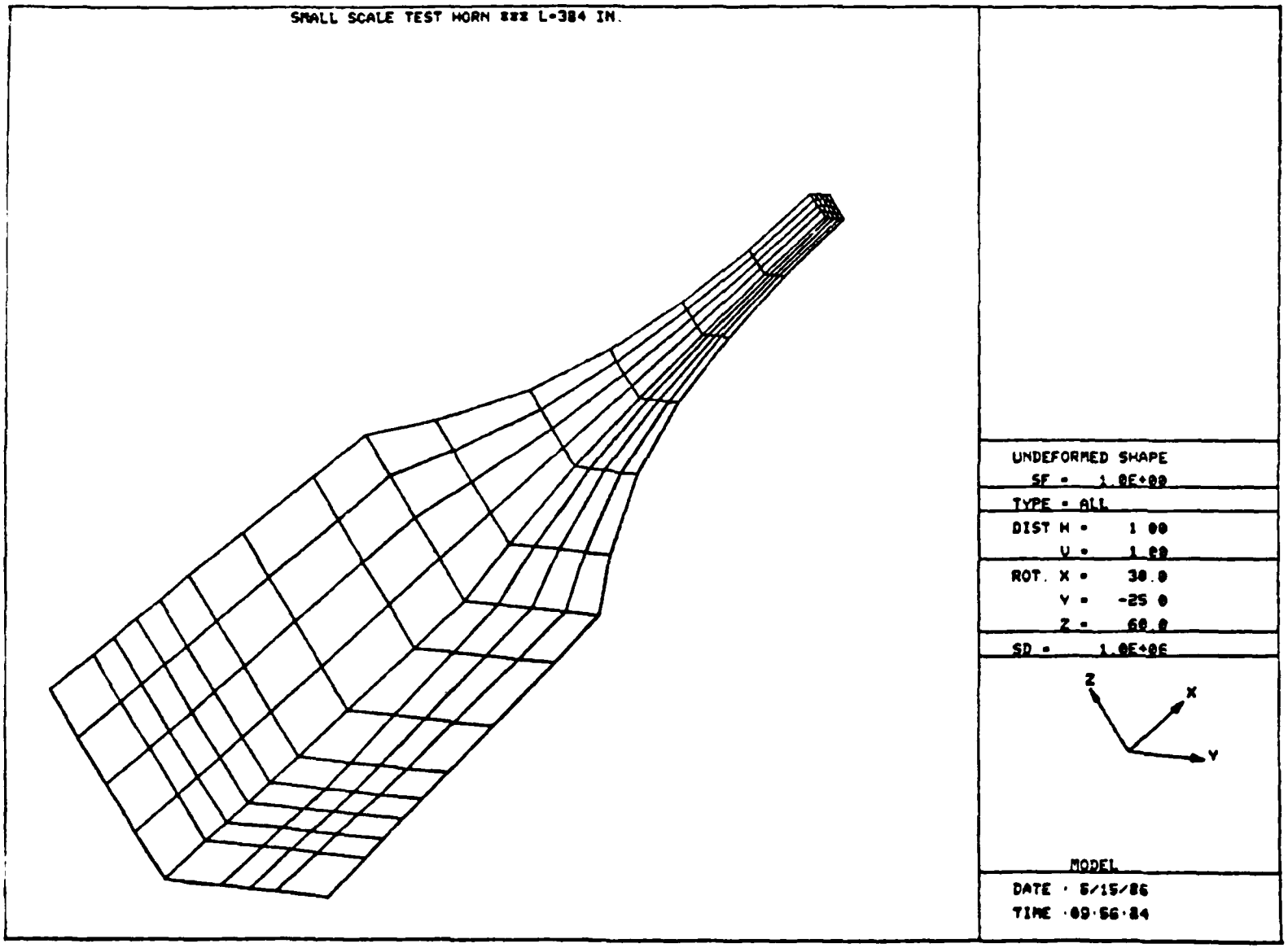

Figure 2 Finite Element Model of the Horn --- L=384 Inches

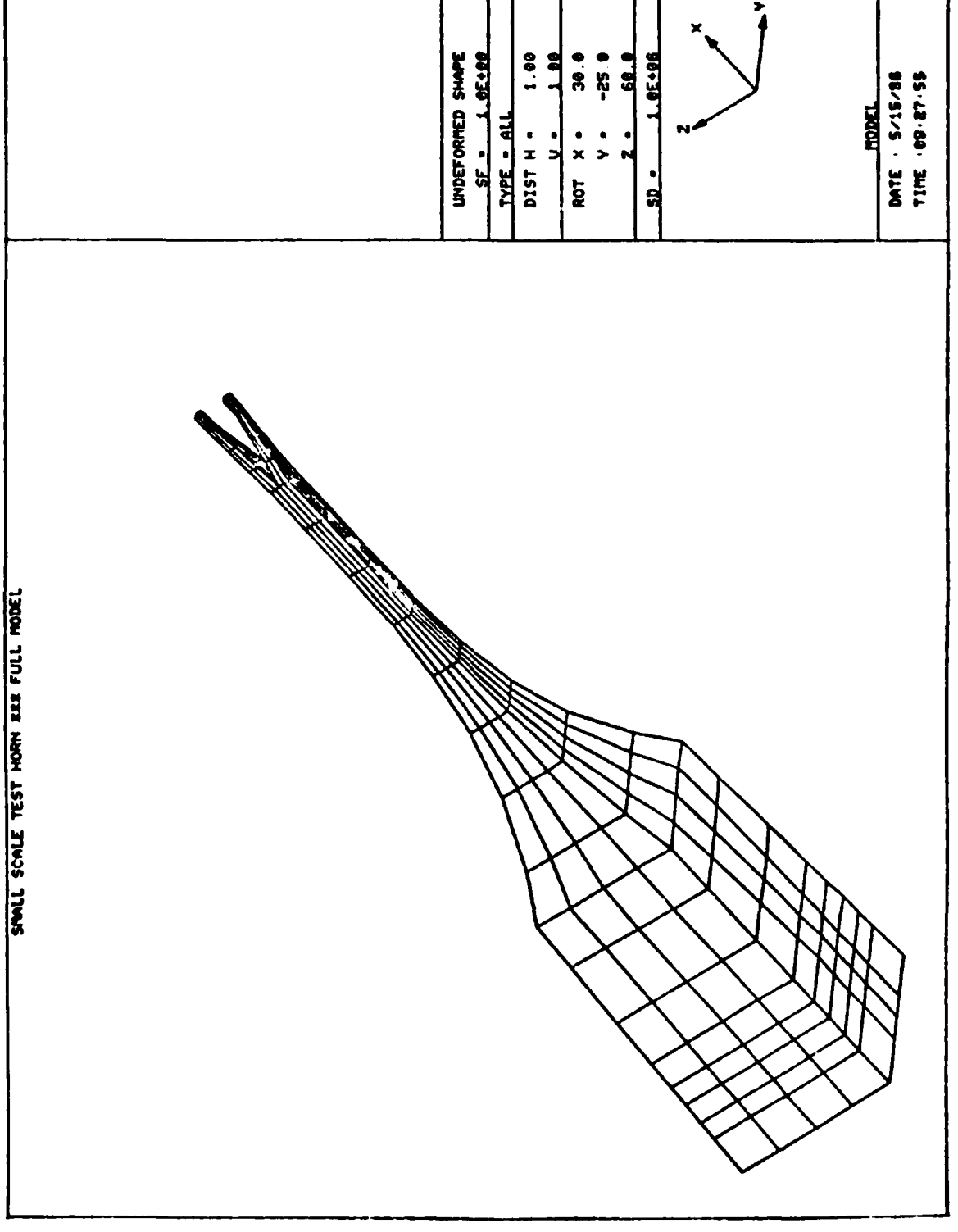

Figure 3 Finite Element Model of the Horn --- L=503 Inches

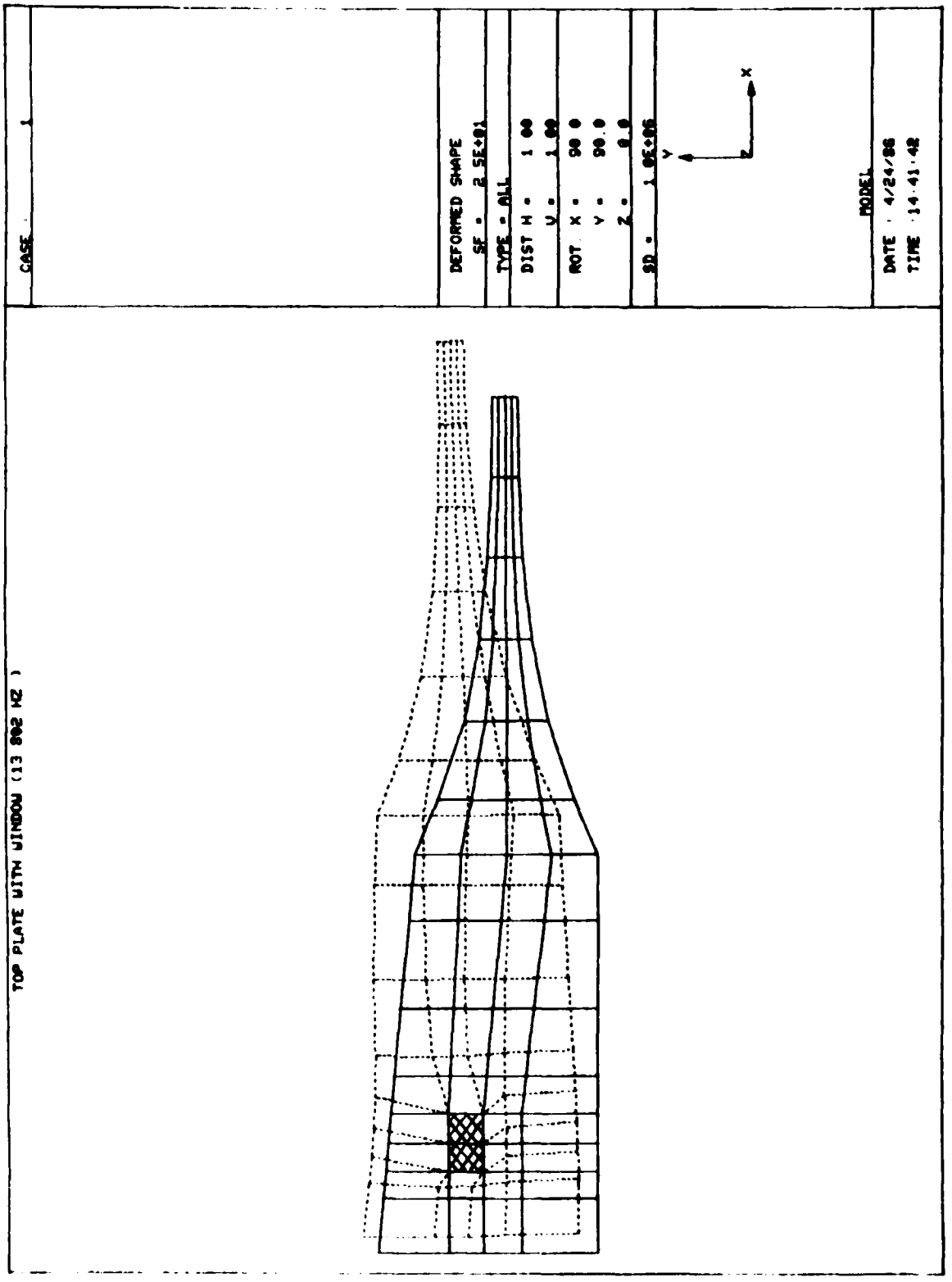

Figure 4 Mode Shapes of Top Plate, L=384 Inches --- Mode (0,0,0)

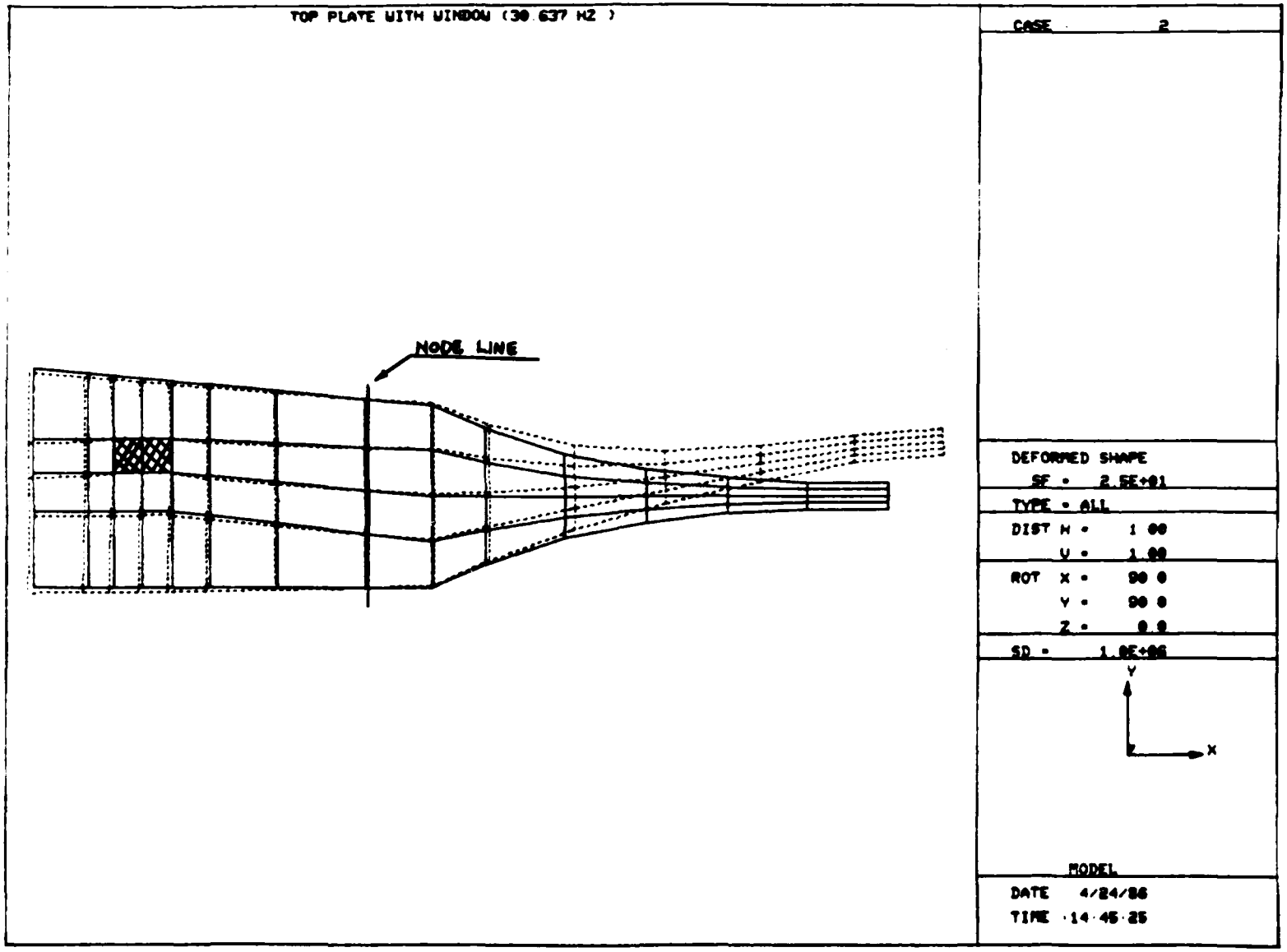

Figure 5 Mode Shapes of Top Plate, L=384 Inches --- Mode (1,0,0)

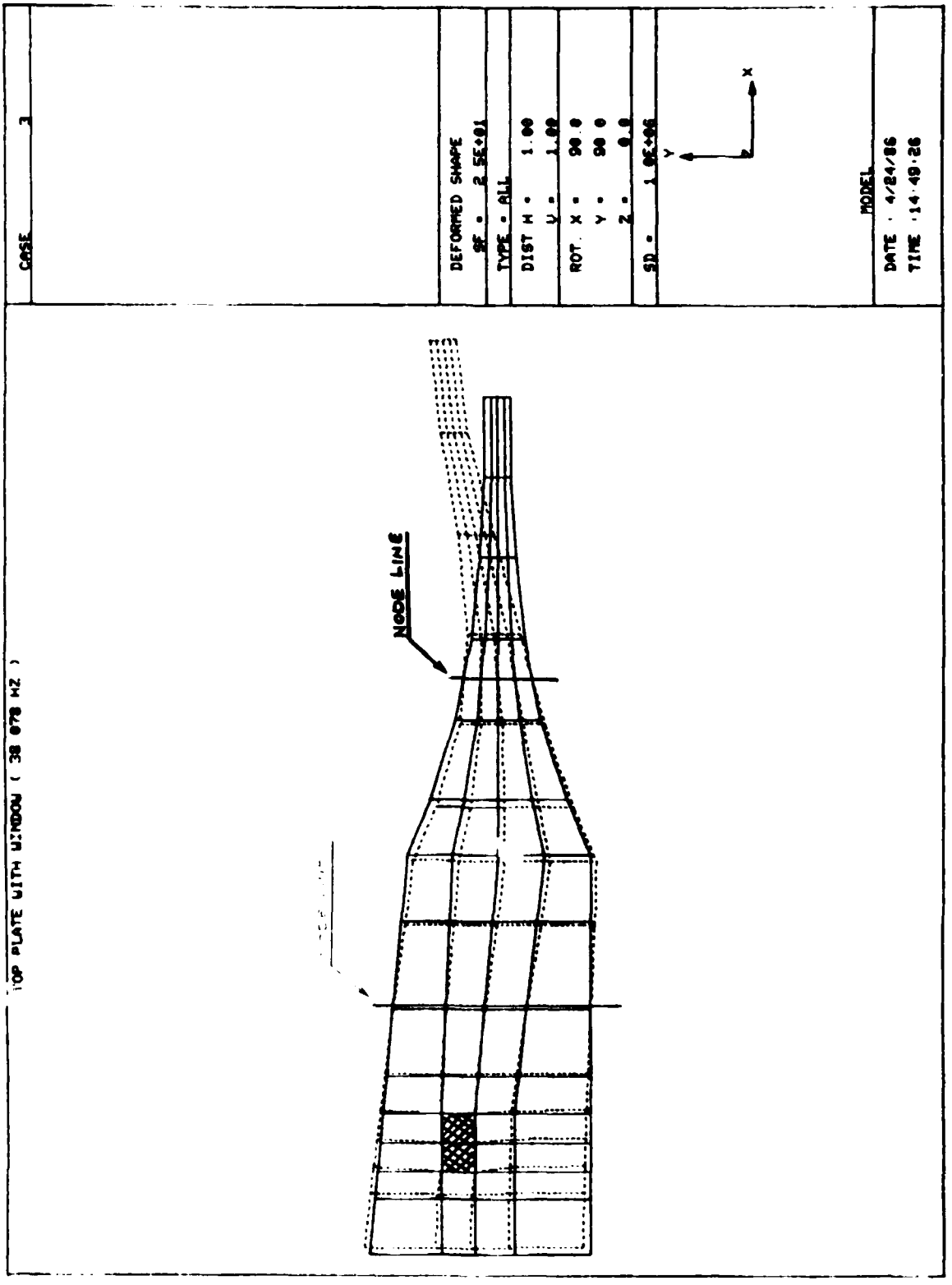

Figure 6 Mode Shapes of Top Plate, L=384 Inches --- Mode (2,0,0)

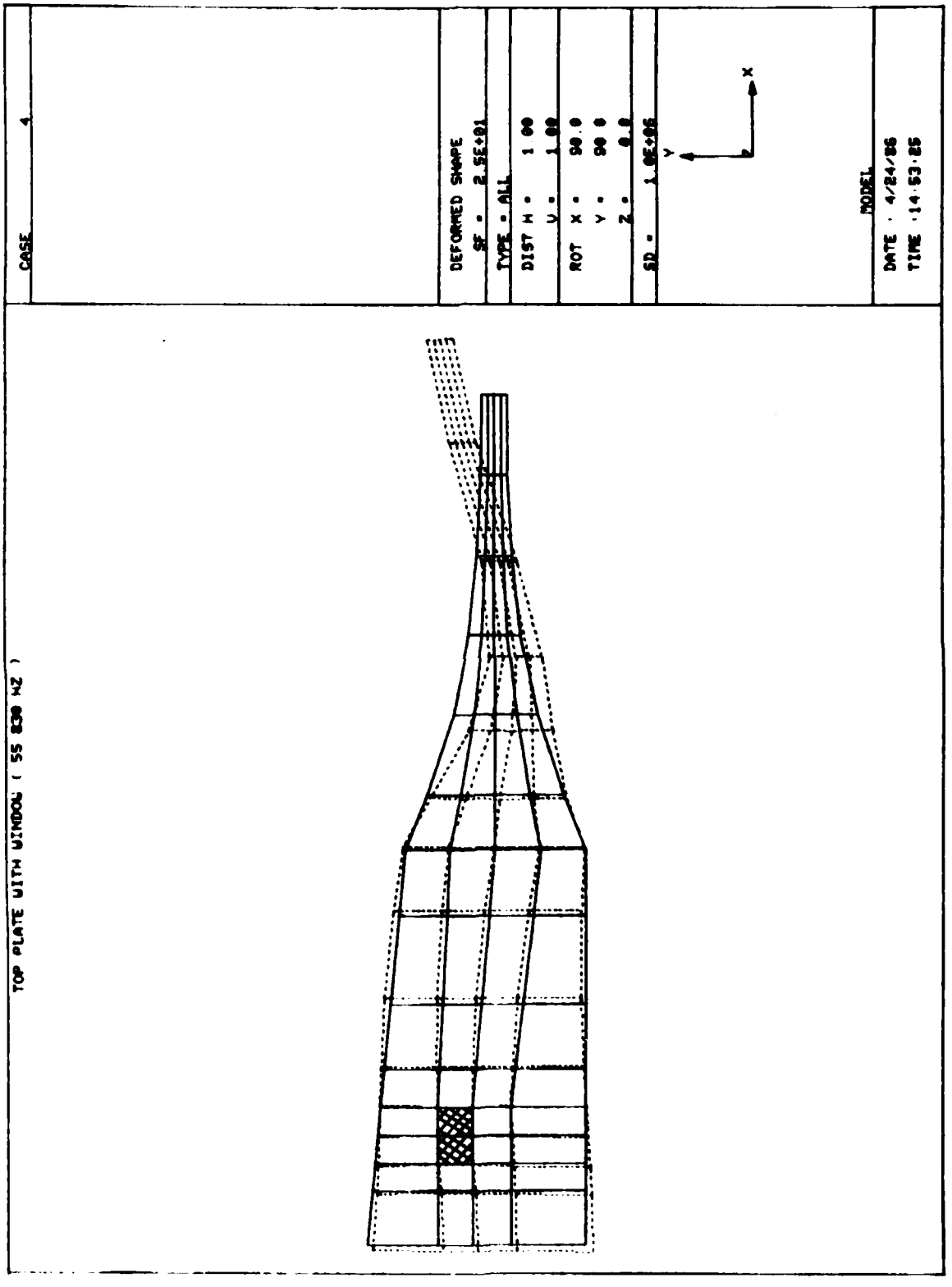

Figure 7 Mode Shapes of Top Plate, L=384 Inches --- Mode (3,0,0)

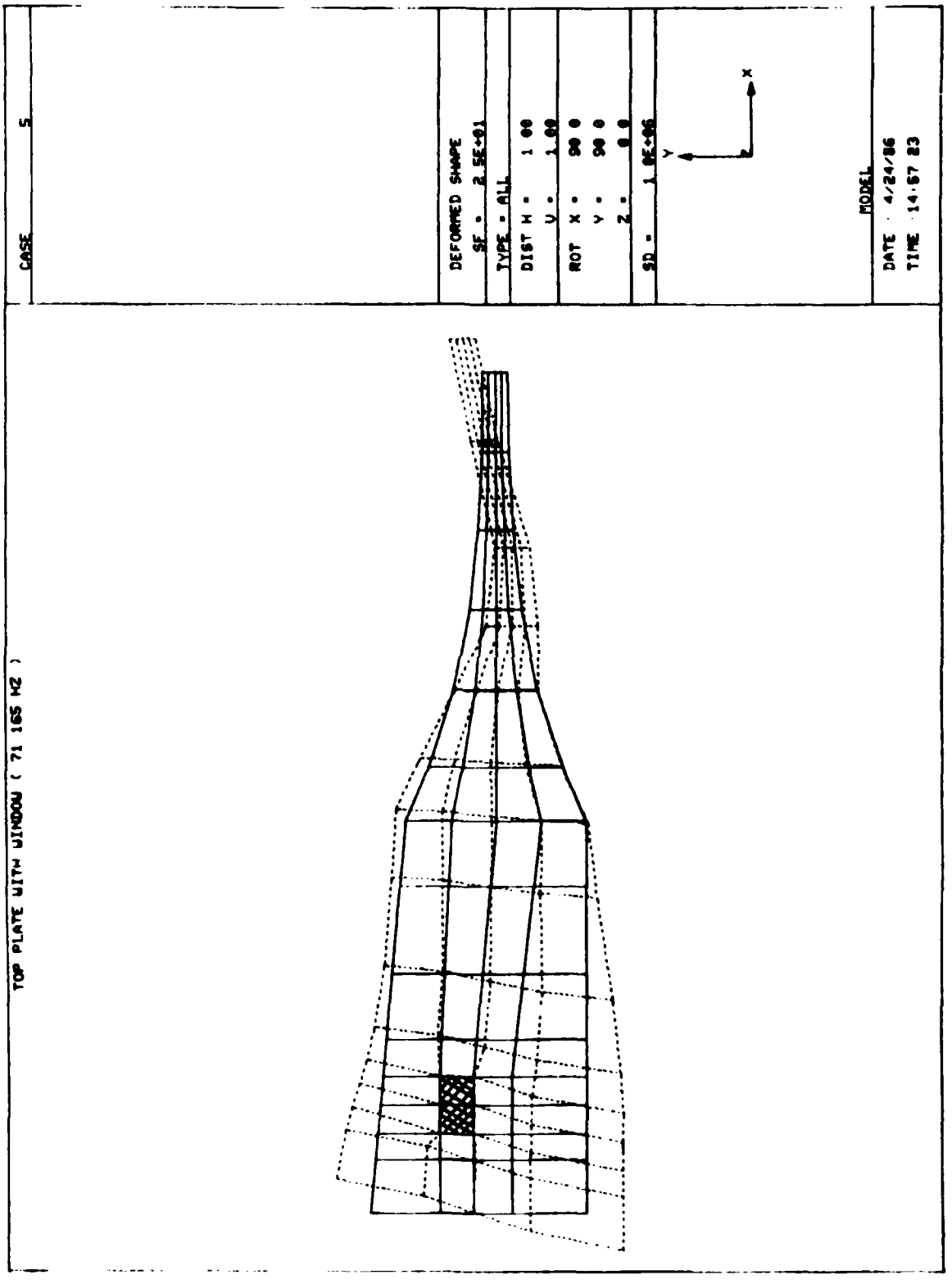

Figure 8 Mode Shapes of Top Plate, L=384 Inches --- Mode (2,1,0)

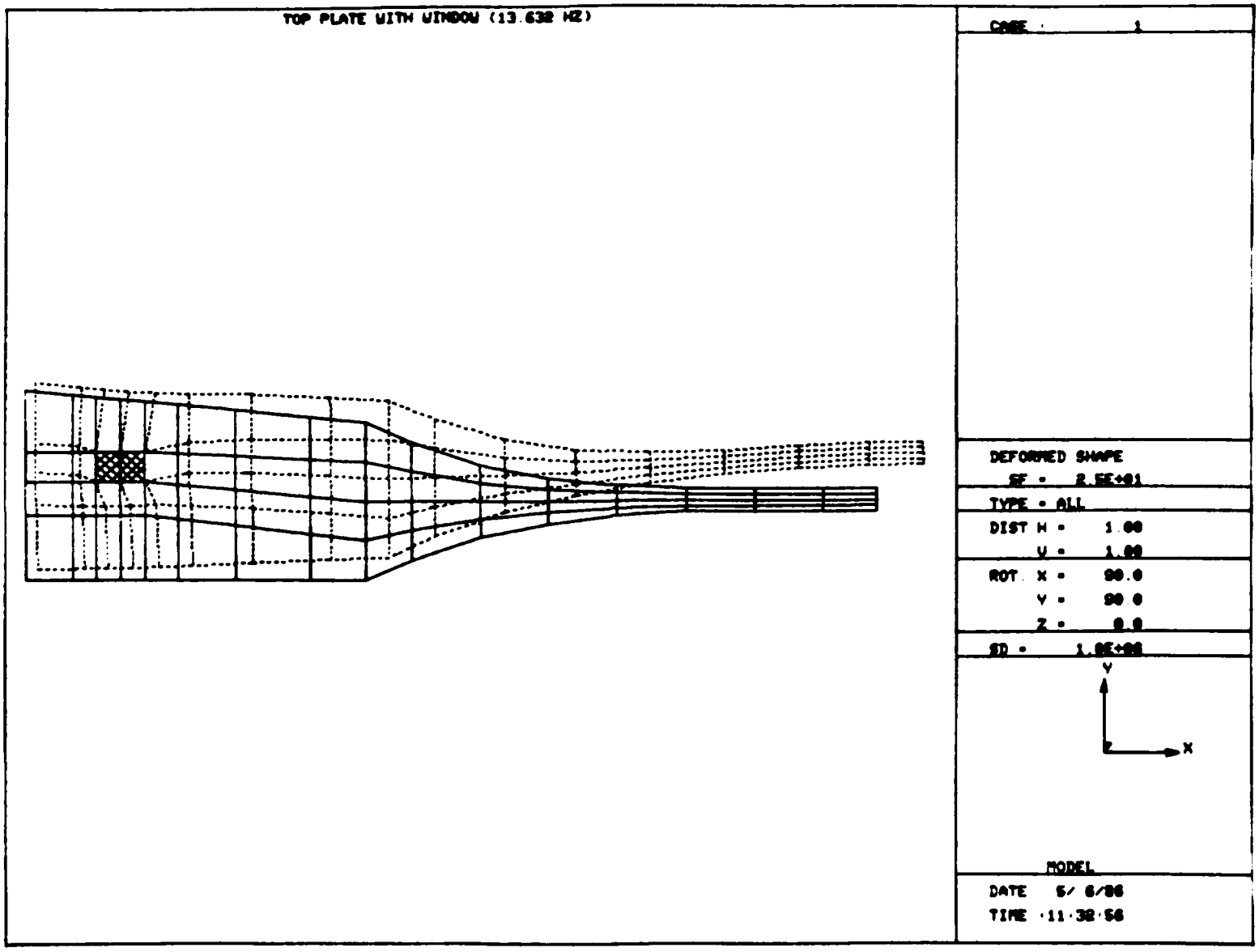

Figure 9 Mode Shapes of Top Plate, L=448 Inches --- Mode (0,0,0)

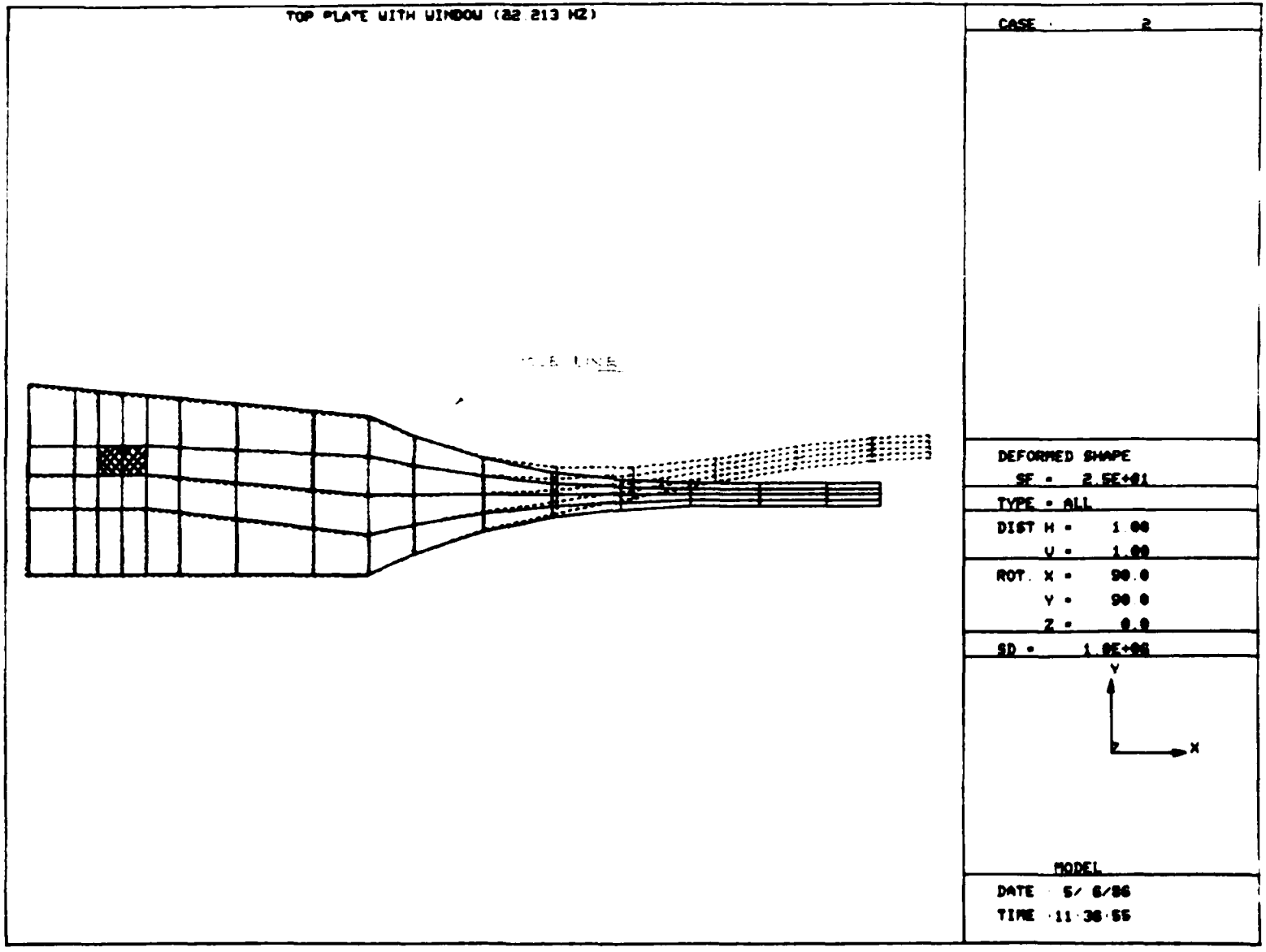

Figure 10 Mode Shapes of Top Plate, L=448 Inches --- Mode (1,0,0)

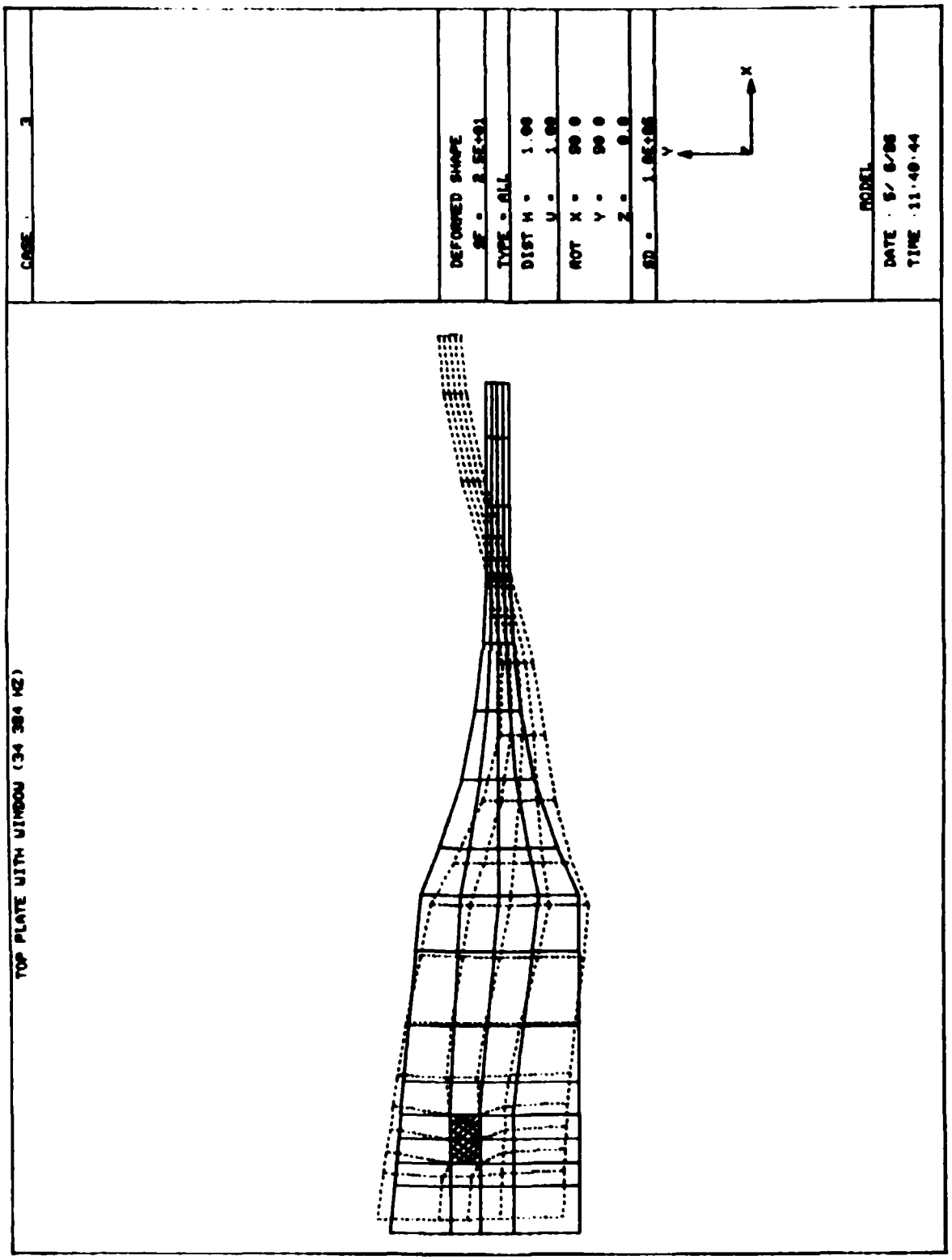

Figure 11 Mode Shapes of Top Plate, L=448 Inches --- Mode (2,0,0)

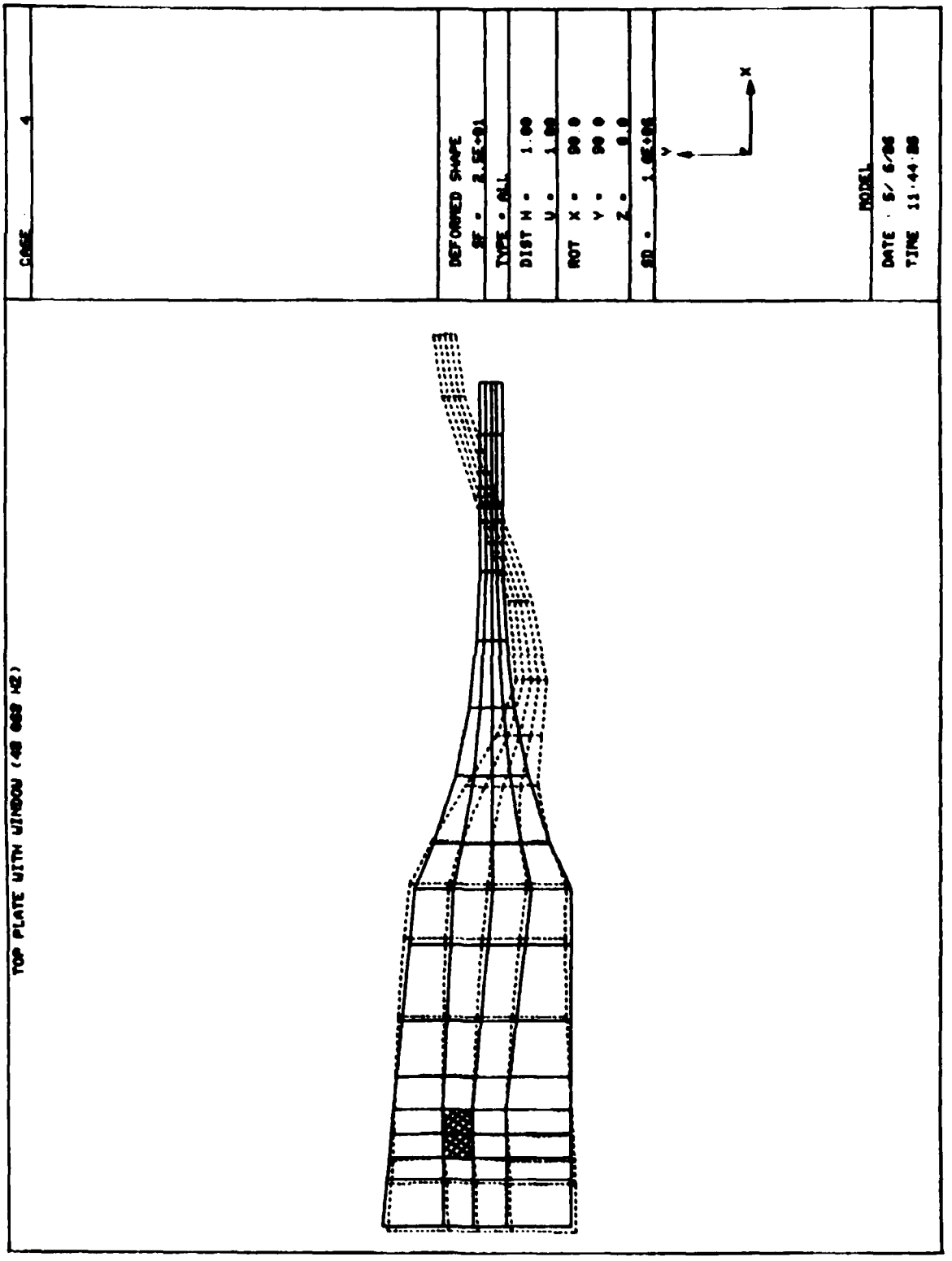

Figure 12 Mode Shapes of Top Plate, L=448 Inches --- Mode (3,0,0)

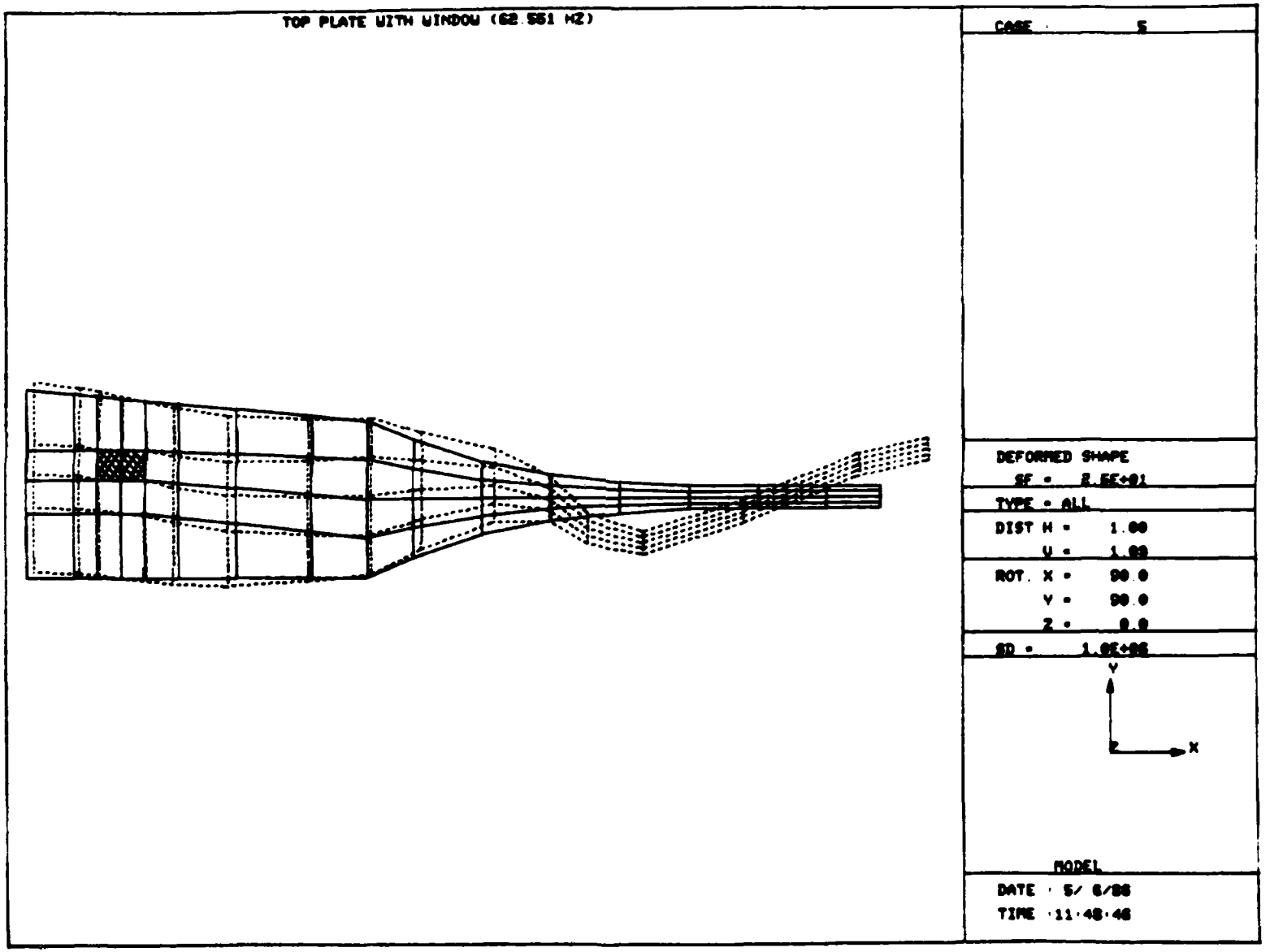

Figure 13 Mode Shapes of Top Plate, L=448 Inches --- Mode (4,0,0)

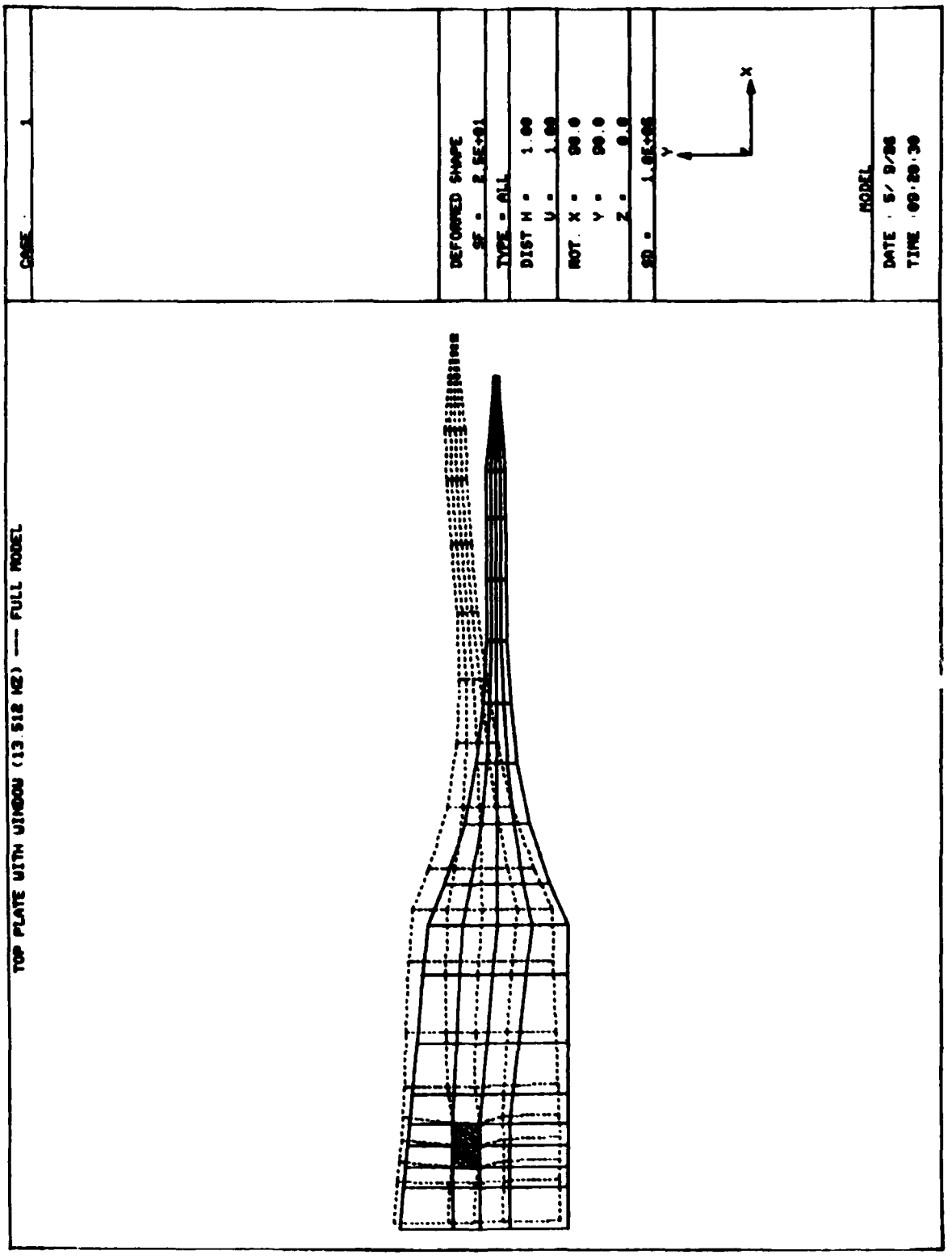

Figure 14 Mode Shapes of Top Plate, L=503 Inches --- Mode (0,0,0)

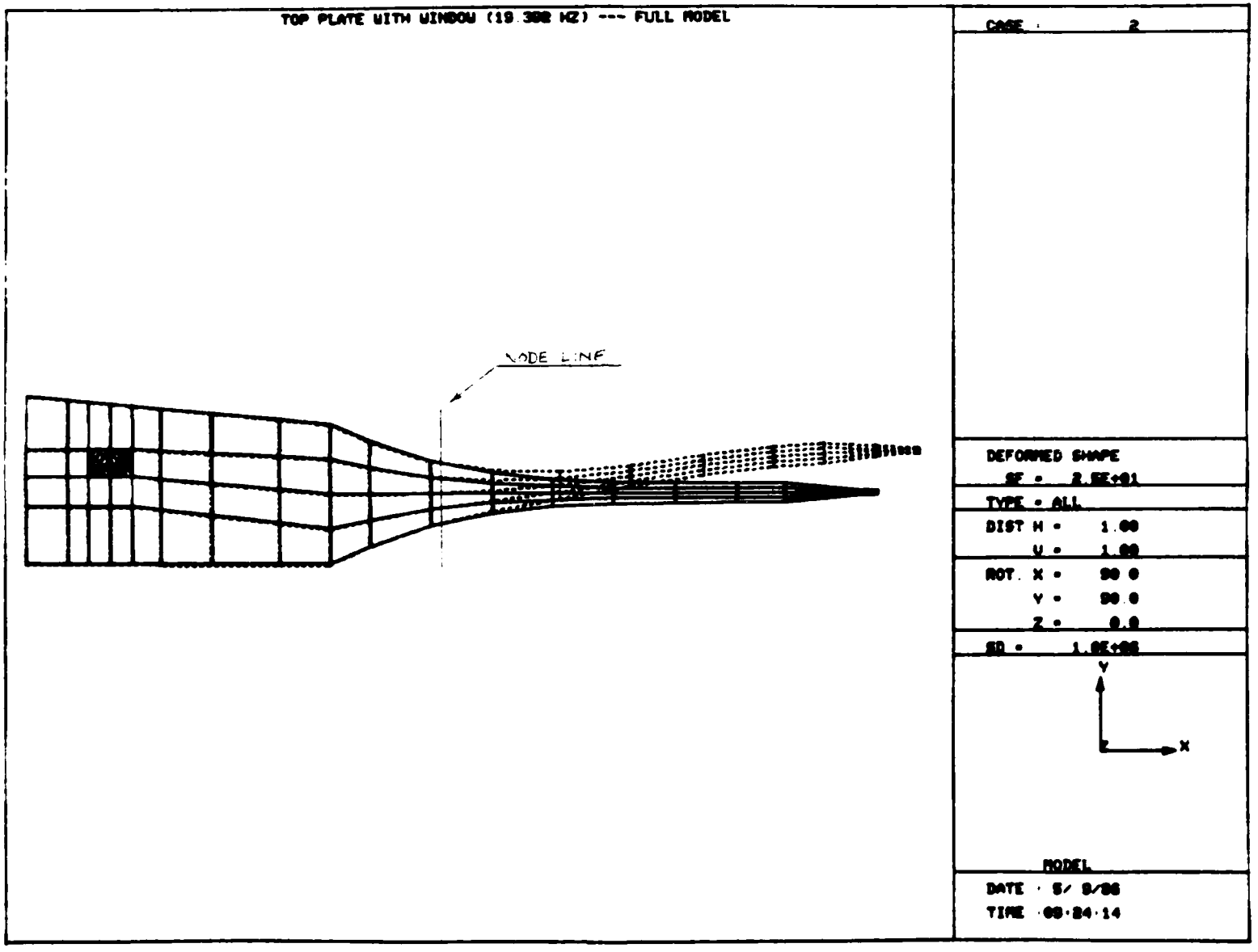

Figure 15 Mode Shapes of Top Plate, L=503 Inches --- Mode (1,0,0)

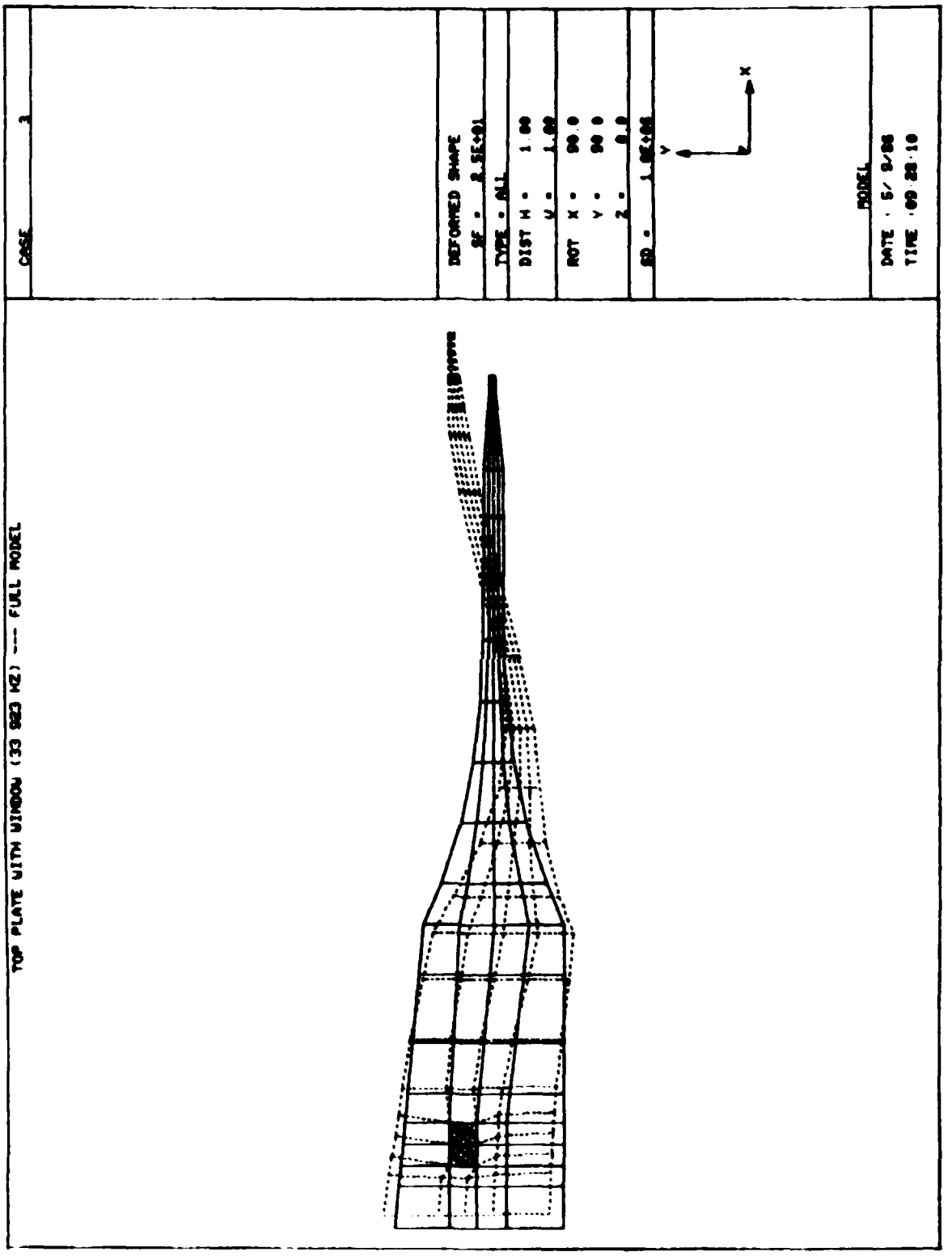

Figure 16 Mode Shapes of Top Plate, L=503 Inches --- Mode (2,0,0)

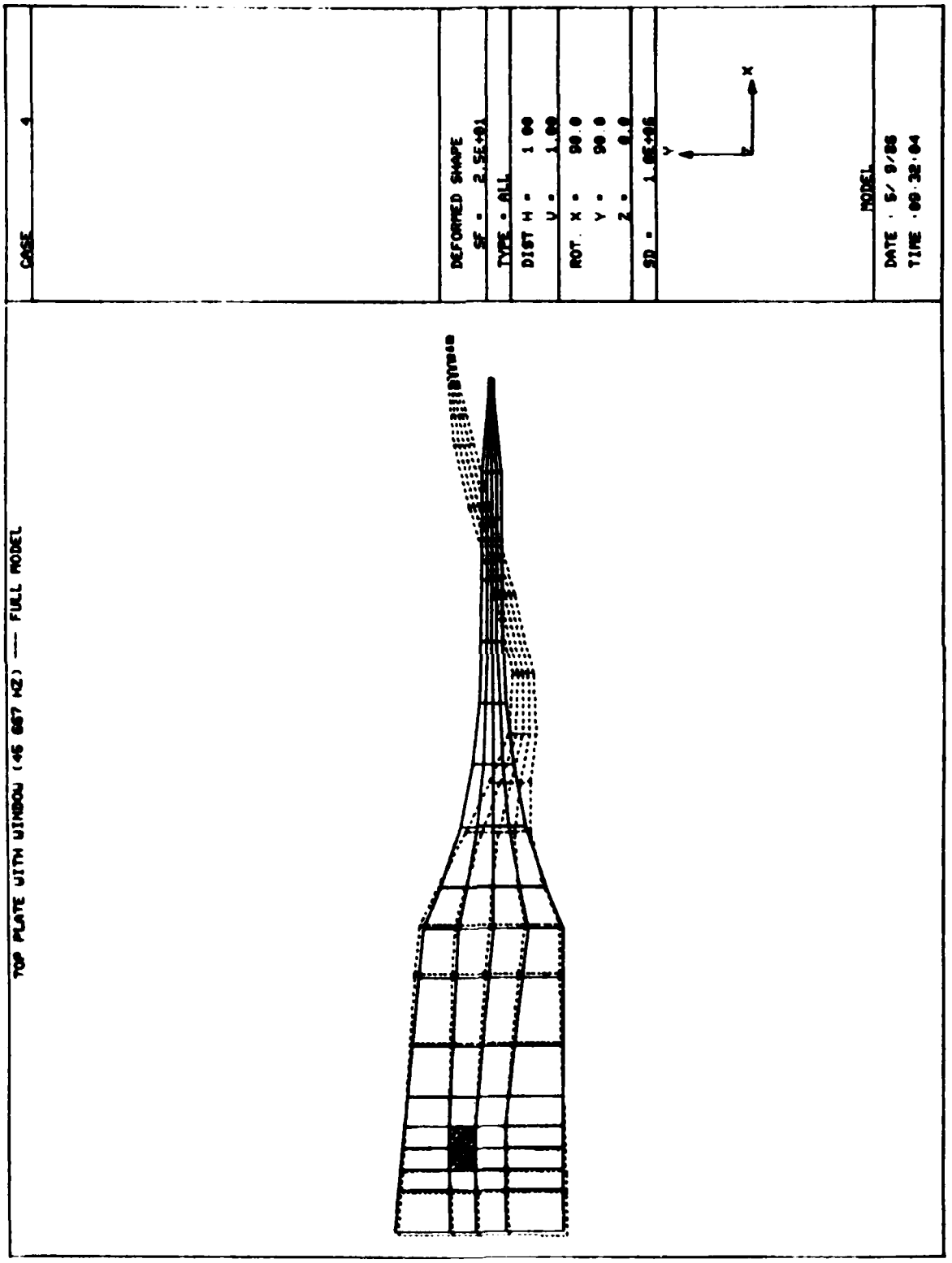

Figure 17 Mode Shapes of Top Plate, L=503 Inches --- Mode (3,0,0)

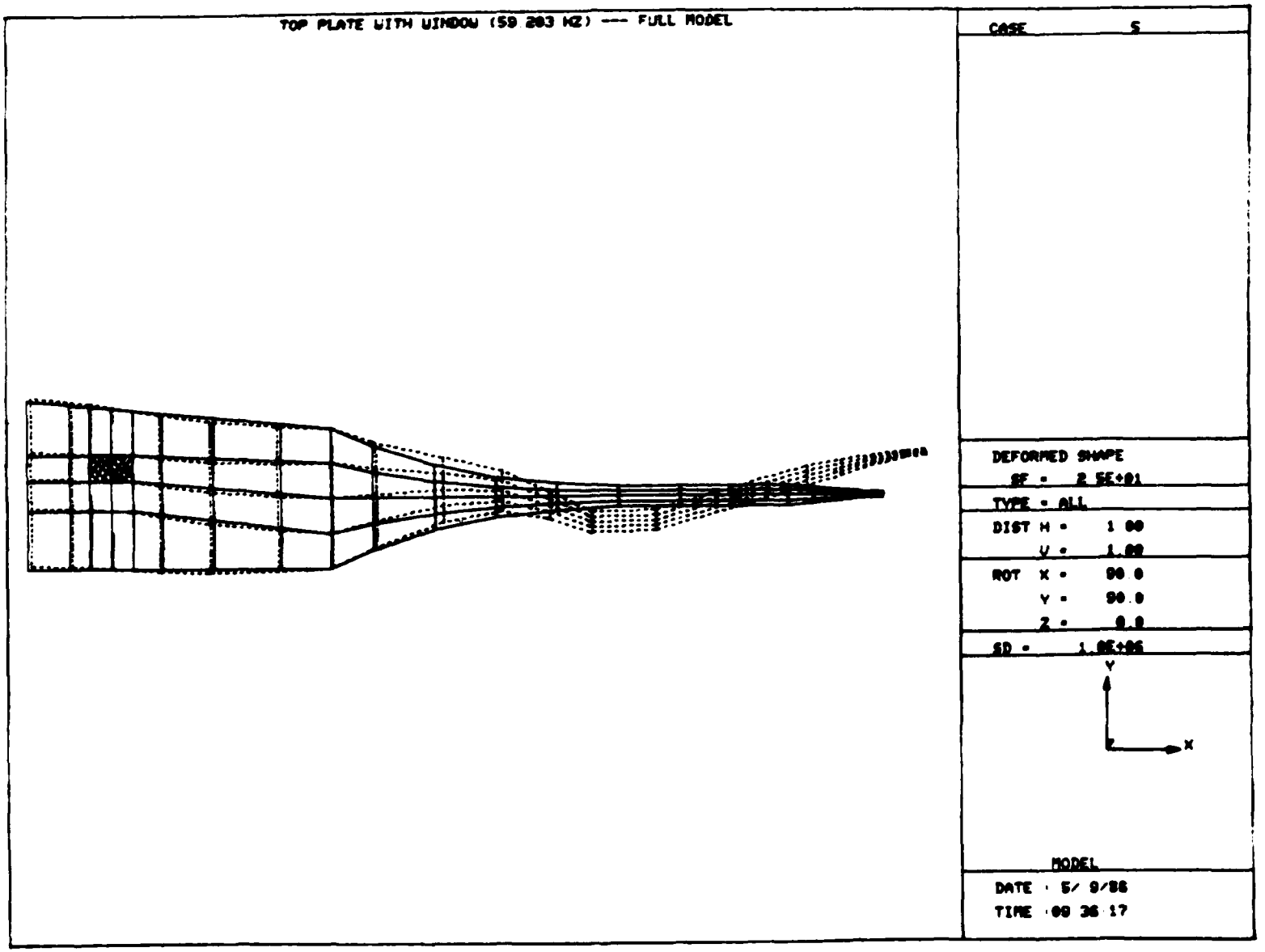

Figure 18 Mode Shapes of Top Plate, L=503 Inches --- Mode (4,0,0)

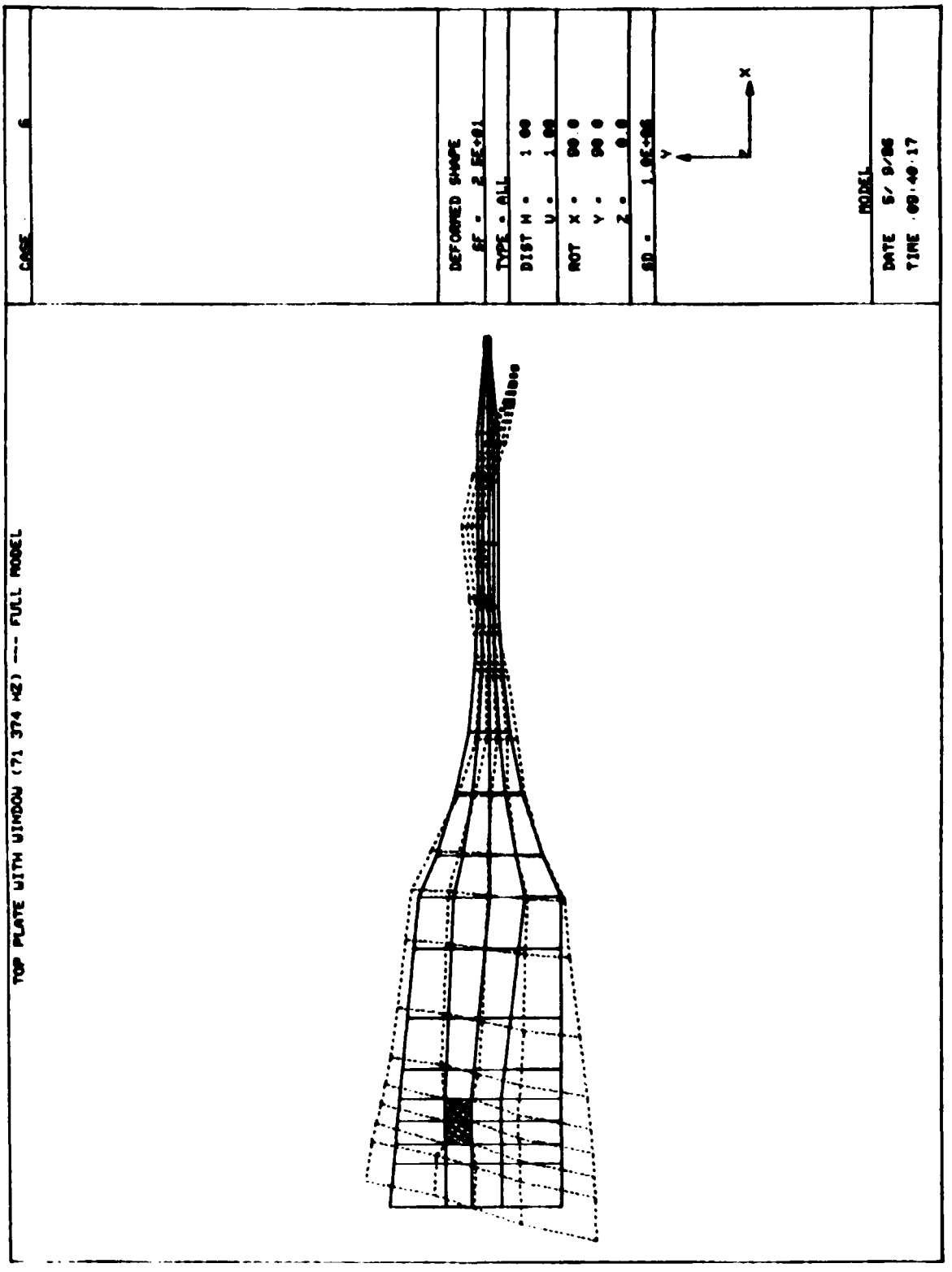

Figure 19 Mode Shapes of Top Plate, L=503 Inches --- Mode (3,1,0)

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